HEWLETT PACKARD

LOW FREQUENCY STANDARD

MODEL: 100D

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100D

HEWLETT-PACKARD COMPANY / OPERATING AND SERVICE MANUAL

100D

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CERTIFICATION

THE HEWLETT-PACKARD COMPANY CERTIFIES THAT THIS INSTRUMENT WAS THOROUGHLY TESTED AND INSPECTED AND FOUND TO MEET ITS PUBLISHED SPECIFICATIONS WHEN IT WAS SHIPPED FROM THE FACTORY.

hp FURTHER CERTIFIES THAT ITS CALIBRATION MEASUREMENTS ARE TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS TO THE EXTENT ALLOWED BY THE BUREAU'S CALIBRATION FACILITY.

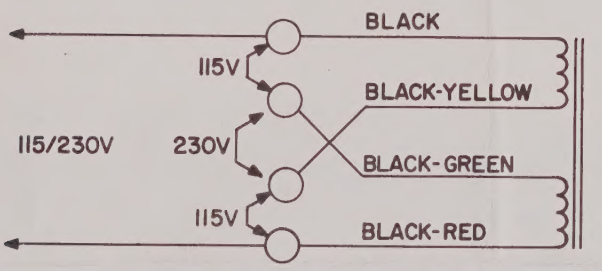
SERVICE NOTE

P-9100-0018

STOCK NO. 9100-0018
(formerly 910-69)

REPLACEMENT POWER TRANSFORMER

PRIMARY CONNECTIONS



SECONDARY CONNECTIONS

WIRE COLOR	WINDING
Red 6 V14 Red 4 V14	930 volts rms at 90 ma.
Red-yellow GRN	Center tap of 930 volt winding
Yellow 2 V14 Yellow 8 V14	5.0 volts rms at 2.0 amps
Green R73 Green I1	6.3 volts rms at 5.25 amps
Brown 2 V15 Brown 7 V15	6.3 volts rms at 2.8 amps

01671-2

Rev. 6/64-15

COMPLETE COVERAGE IN
ELECTRONIC MEASURING EQUIPMENT

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780 v 2.5 mm

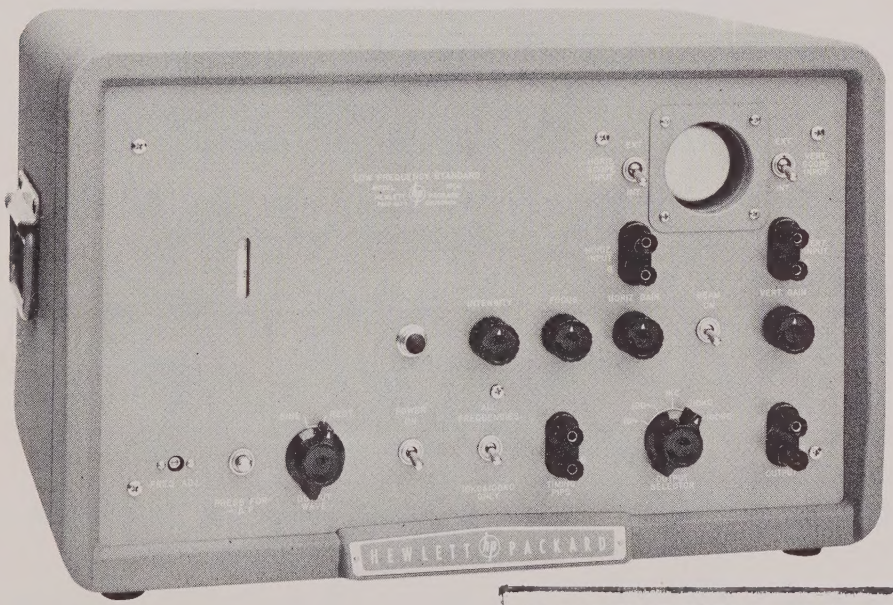
OPERATING AND SERVICING MANUAL

FOR

MODEL 100D

LOW FREQUENCY STANDARD

All Serials



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HEWLETT-PACKARD COMPANY
PAGE MILL ROAD, PALO ALTO, CALIFORNIA, U.S.A.

1403-1

SPECIFICATIONS

FREQUENCY: 100 kilocycles ± .001%
10 Kilocycles
1 kilocycle
100 cycles
10 cycles

STABILITY: 2 parts/million/week
1 part/million/short time intervals

SINE WAVE OUTPUT: Fixed, 5 volts rms, minimum, each frequency

RATED LOAD: 5000 ohms resistive (nominal)

INTERNAL IMPEDANCE: 200 ohms, approximate

DISTORTION: 4% or less using 5000-ohm rated load

RECTANGULAR WAVE OUTPUT: Available at 10 cps, 100 cps, 1 kc, and 10 kc

TIMING PIP OUTPUT:

Interval	Amplitude
100 μsec.	-
1000 μsec.	Twice 100 μsec amplitude
10,000 μ sec.	Triple 100 μsec amplitude

POWER: 115/230 volts ±10%, 50 to 1000 cps ac. 150 watts

WEIGHT: Cabinet: net 44 lbs, shipping 80 lbs
Rack: net 37 lbs, shipping 74 lbs

DIMENSIONS: Cabinet Mount: 12-1/2" high
20-1/2" wide
14-1/2" deep

Rack Mount: 10-1/2" high
19" wide
14-1/4" deep

(Oscillator and Divider Sections ONLY)

To adapt this manual to instruments with other serial prefixes check for errata below, and make changes shown in tables.

Instrument Serial Number	Make Manual Changes
1020 to 1070	1,2,3
762 to 1019	1,2,3,4
692 to 761	1,2,3,4,5
536 to 691	1,4,5,6
518 to 535	1,4,5,6,7
493 to 517	1,4,5,6,7,8

Instrument Serial Number	Make Manual Changes
236 to 492	1,4,5,6,7,8,9
198 to 235	1,4,5,6,7,8,9,10
142 to 197	1,4,5,6,7,8,9,10,11,12
86 to 141	1,4,5,6,7,8,9,10,12,13
5 to 85	1,4,5,6,7,8,10,11,12,13
1 to 4	1,4,5,6,7,8,10,12,13,14

CHANGE 1

C66 through C69: Delete
R8, 35: Change to 470K ohms, hp Stock No. 0690-4741.
R12: Change to 1.5M, hp Stock No. 0690-1551.

CHANGE 2

R9, 18: Change to 2700 ohms, hp Stock No. 0690-2721.
R27: Change to 3300 ohms, hp Stock No. 0690-3321.
R36: Change to 3900 ohms, hp Stock No. 0690-3921.

CHANGE 3

R17, 26: Change to 820K ohms, hp Stock No. 0690-8241.
R21, 30: Change to 1.2M, hp Stock No. 0690-1251.
R40: Change to 1.8M, hp Stock No. 0690-1851.

CHANGE 4

R6, 14, 23 and 32: Change to 5000 ohms, hp Stock No. 2100-0006.

CHANGE 5

R115, 116: Delete

CHANGE 6

R9, 18: Change to 3300 ohm resistor.
R27: Change to 3900 ohm resistor.
R36: Change to 4700 ohm resistor.
R17, 26: Change to 470K ohm resistor.
R21, 30, 40: Change to 1.5M resistor.

CHANGE 7

R5, 7, 13, 15, 22, 24, 31 and 33: Change to 33K ohm resistor.

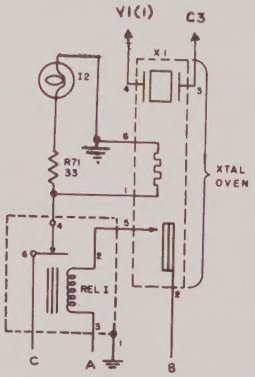
Instrument Serial Prefix	Make Manual Changes	Instrument Serial Prefix	Make Manual Changes
(see page 1)			

CHANGE 8

Add C6: 300 pf capacitor, connected in parallel with L1.
C5: Change to 10 to 100 pf adjustable capacitor, ℗ Stock No. 0121-0008.
L1: Change to 5.5 µh fixed inductance, ℗ Stock No. 9140-0002.

CHANGE 9

Delete: C61, R109 through R113, and V22.
K1: Change ℗ Stock No. to 0490-0003.
Replace crystal oven heating circuit with the following partial schematic diagram:



CHANGE 10

V9 through V13: Change to type 6BC6.

CHANGE 11

R11, 20: Change to 1.2M resistors.

CHANGE 12

R29: Change to 1.2M resistor.
R38: Change to 1M resistor.

CHANGE 13

R11, 20: Change to 750K ohm resistor.

CHANGE 14

Delete: C59 and S8.
(No PRESS FOR FREQ. switch was included.)

(Power Supply and Oscilloscope Sections ONLY)

To adapt this manual to instruments with other serial prefixes check for errata below, and make changes shown in tables.

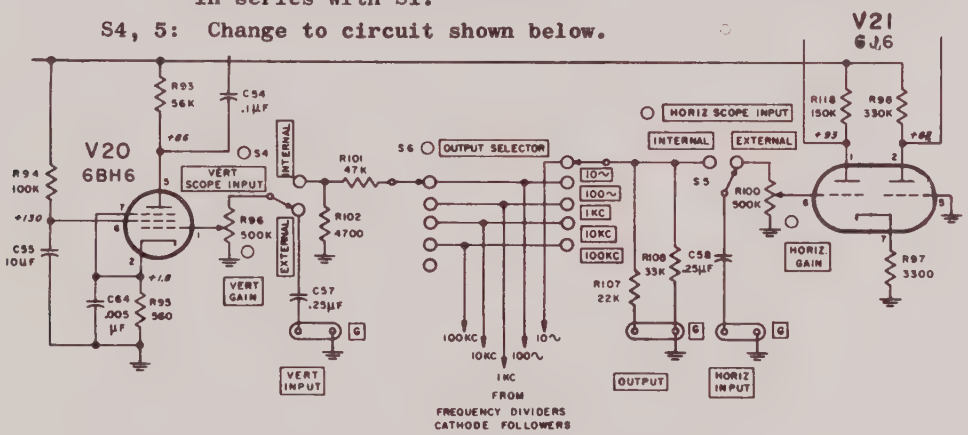
Instrument Serial Number	Make Manual Changes
896 to 1071	1
871 to 895	1 and 2
483 to 870	3
423 to 482	3 and 4

Instrument Serial Number	Make Manual Changes
143 to 422	3, 4 and 5
6 to 141	3, 4, 5 and 6
1 to 5	3, 4, 5, 6 and 7

CHANGE 1

F1: Connect fuse in series with black lead to T1 primary instead of in series with S1.

S4, 5: Change to circuit shown below.



CHANGE 2

R80: Change to 33K ohms ±10%, Ⓗ Stock No. 0690-3331.

R82: Change to 47K ohms ±10%, Ⓗ Stock No. 0690-4731.

CHANGE 3

Change to circuit shown on attached schematic diagram.

CHANGE 4

R114: Delete and replace with wire jumper.

CHANGE 5

Change V9, V10 and V11 heaters to T2.

Manual Changes Model 100D

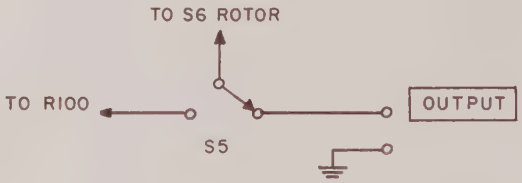
(Power Supply and Oscilloscope Sections ONLY)

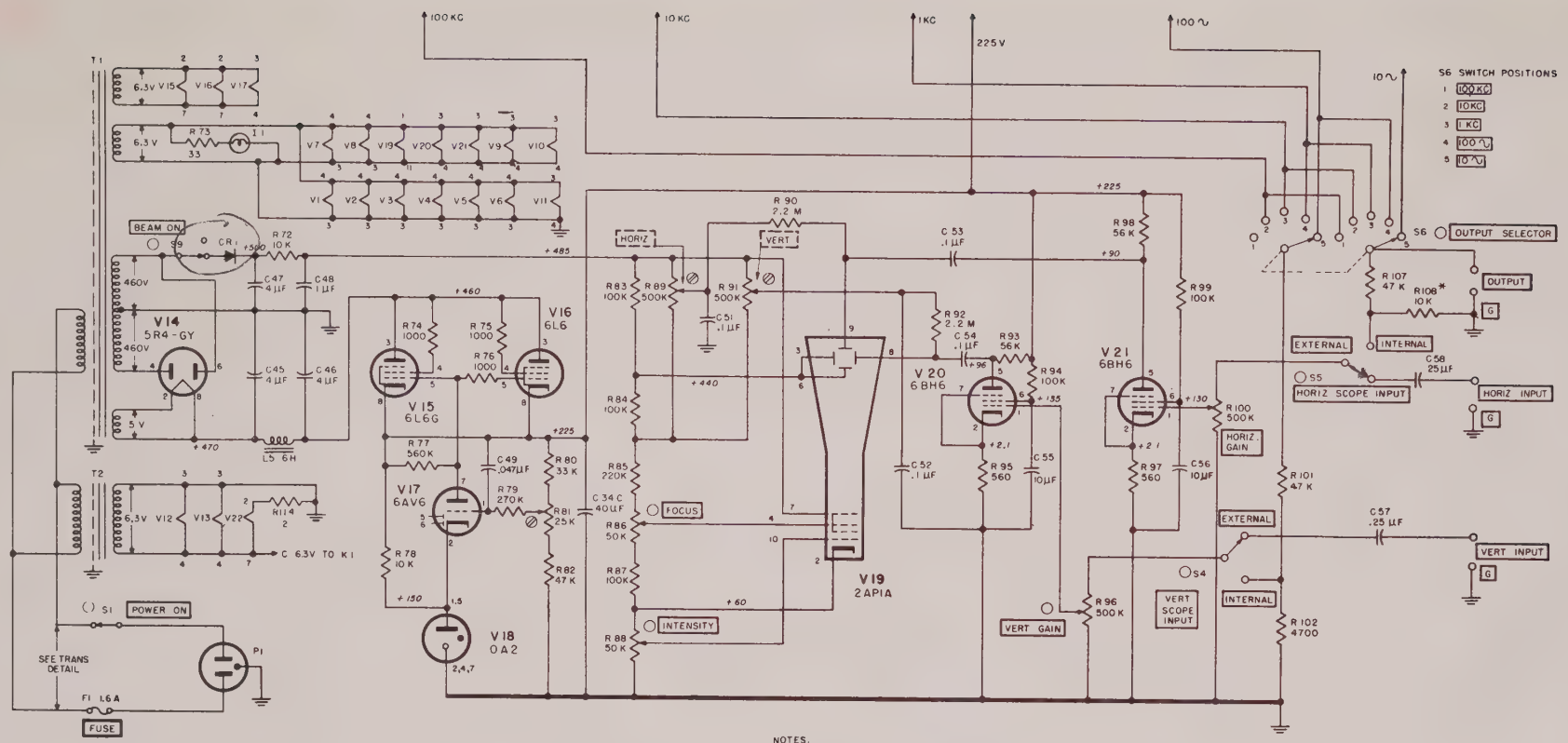
Instrument Serial Number	Make Manual Changes
896 to 1071	1
871 to 895	1 and 2
483 to 870	3
423 to 482	3 and 4

Instrument Serial Number	Make Manual Changes
143 to 422	3, 4 and 5
6 to 141	3, 4, 5 and 6
1 to 5	3, 4, 5, 6 and 7

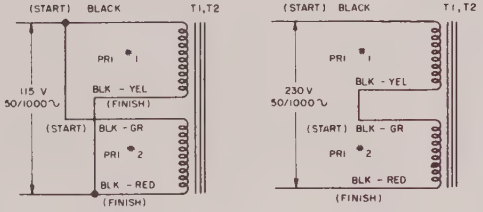
CHANGE 6 — Change V17 to type 6AQ6.

CHANGE 7 — Change circuit of S5 as follows:





TRANSFORMER DETAIL



NOTES.

CAPACITY IN μμF UNLESS OTHERWISE NOTED
K = 1000 OHMS
M = 1 MEGOHM

CONDITIONS OF DC VOLTAGE MEASUREMENT
1 115/230 V, 50/1000 CYCLES POWER SUPPLY
2 VOLTAGES MEASURED BETWEEN THE INDICATED POINTS AND CHASSIS WITH A VOLTMETER OF 122 MEGOHMS INPUT RESISTANCE
3 OUTPUT WAVE SWITCH ON SINE

* ELECTRICAL VALUE ADJUSTED AT THE FACTORY AVERAGE VALUE SHOWN PART MAY BE OMITTED

⊘ SCREWDRIVER ADJUSTMENT [CHASSIS MARKING]
○ PANEL CONTROL [PANEL MARKING]
⏚ CHASSIS

SCHEMATIC DIAGRAM OF MODEL 100D

POWER SUPPLY & OSCILLOSCOPE SECTION

serial # 509 ID-16944

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SECTION I

GENERAL DESCRIPTION

1-1 GENERAL

The Hewlett-Packard Model 100D Low Frequency Standard is a highly stable secondary frequency standard producing standard frequencies of 100 kilocycles, 10 kc, 1 kc, 100 cycles and 10 cycles per second with a stability of 2 parts/million/week and a sinusoidal output of 5 volts rms. The 100D may be conveniently standardized with a primary frequency standard by using the front panel cathode ray tube and adjustment to set the internal oscillator "on frequency". With frequent checks against a primary standard the 100 D offers the benefits of the primary standard at greatly reduced cost.

All five standard frequencies generated by the 100D may be used simultaneously if desired and the waveshape may be either sine wave or, on the four lower frequencies, rectangular waves. In addition to the standard frequency output the 100D also provides timing pips at 100, 1000 and 10,000 microsecond intervals from a separate set of output terminals. A front panel pushbutton switch shifts the 100 kc standard frequency minus one cycle to facilitate indentification of beat-frequency signals.

The front panel cathode ray tube provides a convenient means of comparing internally and externally generated frequencies by means of Lissajous Figures. Both the vertical and horizontal amplifiers are brought through toggle switches to terminals located on the front panel. The cathode ray tube also provides a quick self-check on the operation of each of the four frequency dividers which provide the four lower standard output frequencies.

1-2 ELECTRICAL CHARACTERISTICS

The Model 100D produces five standard output frequencies, 100 kilocycles, 10 kc, 1 kc, 100 cycles and 10 cycles per second. All standard output frequencies are available simultaneously at terminals located on the rear of the instrument chassis. Any one standard frequency as selected by the front panel OUTPUT SELECTOR is available at the front panel OUTPUT terminals. The output voltage from both sets of terminals is fixed at a minimum of 5 volts rms for sine wave output when connected to the rated load of 5000 ohms. Distortion in the output sine wave is less than 4% for all frequencies; the internal impedance is approximately 200 ohms.

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The output waveform of the four lower standard frequencies can be switched by the front panel OUTPUT WAVE switch to a rectangular wave rich in harmonics. Useful harmonics as high as 5 megacycles may be obtained from the 10 kc standard output.

In addition to the standard output frequencies positive marker pulses at three time intervals, 100, 1000 and 10,000 microseconds, are provided simultaneously at the front panel TIMING PIPS terminals. The marker pip pattern is illustrated in Figure 1-2, the 1000 μsec pips being twice and the 10,000 μsec pips three times the amplitude of the 100 μsec pips. When in the 10KC and 100KC ONLY position, the ALL FREQUENCIES 10KC and 100KC ONLY switch removes the 1,000 and 10,000 μsec pips as well as the three lower standard output frequencies.

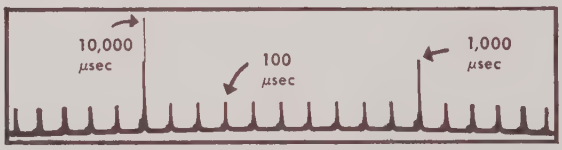

Fig. 1-2 Timing comb, -hp- Model 100D

The basic 100 kc standard frequency is controlled by a specially selected and aged, low temperature coefficient crystal which is housed in a double chamber oven, temperature controlled by a mercury thermostat having a temperature differential of 0.1° C. The oven temperature is held at +65° C and is effective for room temperatures from approximately -10° to +40° C. Control of the oven temperature and the stability of the crystal are such that an overall accuracy within approximately 2 parts/million is obtainable over a period of one week, and as good as 1 part/million for short time intervals, following a 24 hour heat run.

The Model 100D Low Frequency Standard as shipped from Hewlett-Packard is wired for operation on 115-volt, 50 to 1000 cycle, a-c power and uses 150 watts of power. The instrument may be wired for operation on 230-volt a-c power by changing the wiring on the power transformer primary winding as described in paragraph 4-6

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1-3 PHYSICAL CHARACTERISTICS

The Model 100D Low Frequency Standard is a single component portable test equipment constructed for test bench use or for permanent installation in a standard 19 inch relay rack. The instrument cabinet stands 12-1/2 inches high by 20-1/2inches wide by 14-1/2 inches deep. Without the cabinet, i. e. for rack mounting, the corresponding dimensions are 10-1/2 by 19 by 14-1/4 inches. The instrument cabinet is constructed of aluminum alloy finished in -hp- gray wrinkle paint and is fitted with four large rubber feet and two carrying handles. The front panel is finished in gray baked enamel with engraved white lettered control and terminal call outs. The instrument with cabinet weighs 45 pounds.

Front panel output terminals are binding posts spaced 3/4 inch center to center to receive standard two conductor banana plugs or plain wire.

1-4 APPLICATION

The 100D Low Frequency Standard performs most of the functions of primary frequency standards. Some of the more common uses are: calibrating a-f oscillators, r-f oscillators, receivers and transmitters; providing a signal source for bridges and impedance measuring devices; checking the stability of all varieties of electronic equipment; measuring short time intervals and providing highly accurate time and frequency standards.

The internal cathode ray tube serving as a frequency comparitor increases the instruments range of usefulness as a test instrument. The timing pip feature provides useful harmonics of the 10 kc standard output far beyond the fundamental standard output frequency, thus providing a very accurate and effective beat-frequency calibrator for r-f receivers and transmitters up to the high frequency bands.

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SECTION II

OPERATING INSTRUCTIONS

2-1 INSPECTION

This instrument has been thoroughly tested and inspected before being shipped from HEWLETT-PACKARD and is ready for use when received. When unpacking the instrument, look for signs of damage or rough handling Remove the rear cover of the cabinet and inspect the seating of all tubes. If any shipping damage is found, follow the procedure outlined in the "Claim for Damage in Shipment" page at the rear of this manual.

2-2 INSTALLATION (Read before turning equipment on!)

This instrument is equipped with a three conductor power cord terminated in a polarized three prong connector recommended by the National Electrical Manufacturers' Association The plug is similar to the popular two prong plug with the addition of a long round ground pin. When used with the appropriate receptacle, this plug will connect the instrument chassis to ground for the protection of operating personnel. The plug may be used with a two conductor outlet by means of a readily available adapter. The adapter will terminate the instrument ground in a short green wire which should be connected to a suitable ground.

The crystal oven in this instrument is regulated by a mercury-column switch. The mercury in the column can become separated by jarring and vibration. When first turning on the instrument keep a close check on the oven temperature as indicated by the thermometer on the front panel. When the frequency standard has been on for approximately 30 minutes the oven temperature should settle at a constant $65^{\circ} \pm 2^{\circ}$. At this time the oven thermometer

illuminating lamp should turn off from time to time indicating when the heater turns off. If the thermometer illumination remains on continuously and/or the thermometer rises much above 65°, the mercury column in either the thermostat or thermometer may have been separated in shipment. Turn the instrument off immediately and proceed as follows:

1. Refer to Fig. 4-1. Remove crystal oven and clamp.

2. Remove the two nuts and clamp holding thermometer in oven. Withdraw thermometer by straight pull.

3. Inspect thermometer for separation or air bubbles in the mercury column. If there is a separation or there are air bubbles in the mercury column, place bulb in ice water until all mercury is contained in bulb. If necessary, tap lightly to remove any bubbles or mercury globules left in the column.

4. Place thermometer in water and heat until mercury completely fills column. Remove the thermometer and watch the mercury descend to room temperature point. If there is no separation or air bubbles present, the thermometer may be put back in service. If necessary, repeat the above procedure until mercury is entirely united.

5. To check thermostatic switch, remove the two thermostat wires from terminals on lower side of the oven.

6. Remove the two mounting screws and clamp holding the thermostat. Draw thermostat out of oven by straight pull.

> **CAUTION**
>
> In the following steps, immerse only the thermostat bulb in water being careful to keep the wire leads completely dry. Allow no moisture to collect beneath the plastic insulator covering the contact rings, otherwise electrical leakage between the two ring contacts may cause the heater relay to remain open.

7. Inspect thermostat for mercury column separation or minute air bubbles in the mercury bulb. If there is a separation or there are bubbles, place bulb in ice water until all mercury is contained in the bulb. If necessary, tap lightly to remove any bubbles or mercury globules left in the column.

8. Place the bulb in a vessel of water and heat until mercury completely fills column and a small portion of the enlargement at top of column. Remove thermostat and watch the mercury descend to room temperature. If there is no separation or bubbles present, the thermostat may be put back into service. It may be necessary to repeat the above procedure to completely unite the entire mercury column.

2-3 LOCATING THE FREQUENCY STANDARD

The hp Model 100D Low Frequency Standard is constructed for test bench or relay rack use and is not intended for mobile use. The 100D should be placed on a bench convenient to other equipment with which it will be used and left unmoved as much as possible. For greatest stability, the frequency standard should be run continuously. Turning the instrument off allows the crystal temperature to fall, consequently, requiring a new "run in" period before best stability is obtained. At all times the frequency standard should be protected from unnecessary vibration and mechanical shock.

It is possible to locate the frequency standard centrally to various wide-spread equipment and to use very low capacity shielded cable to distribute the standard frequencies to other instruments. A table in paragraph 2-4 indicates the permissable capacitive loading on each output terminal for such a test setup.

When selecting a location for the standard, provide good air circulation. The louvers in the cabinet provide sufficient circulation if they are not obstructed. Inadequate ventilation can cause the ambient temperature in the instrument to rise high enough so that the oven thermostat may lose control. Note oven temperature thermometer regularly for any variation in temperature.

2-4 USING SHIELDED WIRE CONNECTING LEADS

Low capacity shielded wire should be used to distribute the standard frequency output voltages to equipment under test. Noise pick-up and signal leakage between cables is thus held to a minimum. The total capacity that can be used on one set of output terminals without exceeding the 5000-ohm rated load is listed below.

Standard Frequency	Max. Load Capacity	Approx. Length of RG-58/U	Approx. length of RG-62/U
100 kc	300 μμf	11 feet	22 feet
10 kc	3000 μμf	111 feet	220 feet
1 kc	.03 μf	1100 feet	2200 feet
100 cps	.3 μf		
10 cps	3 μf		

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The length of the shielded lead used on the 100 kc output may be lengthened if the line is terminated in an inductor and tuning capacitor which can be tuned to 100 kc for maximum output.

2-5 OPERATING CONTROLS AND TERMINALS

The front panel operating controls and terminals for the 100D are listed with their functions in the following table.

CONTROLS AND TERMINALS

	Designation	Function
1	POWER ON (switch)	Turns on all power supplied to the instrument from the power line.
2	OUTPUT SELECTOR (switch)	Selects the standard output frequency fed to the "OUTPUT" binding posts on the front panel and the oscilloscope input switches.
3	OUTPUT WAVE (switch)	Provides a choice of sine or rectangular wave shape in the output voltage at all frequencies.
4	ALL FREQUENCIES 10 kc & 100 kc ONLY (switch)	Turns off the three lower standard frequencies and the two longer timing pip intervals.
5	OUTPUT (Terminals)	Provide the standard output frequency selected by the OUTPUT SELECTOR.
6	OUTPUT BINDING Posts	The five sets of terminals on the back of the chassis are the output terminals for each of the five frequencies generated by the instrument. Binding posts marked "G" are connected to the chassis.

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CONTROLS AND TERMINALS (CONT'D)

	Designation	Function
7	TIMING PIPS (terminals)	Supplies timing pips at 100, 1000, 10,000 μsec intervals, simultaneously.
8	BEAM ON (switch)	Turns on cathode ray tube beam.
9	HORIZ. SCOPE INPUT - EXT. INT. (switch)	Connects the horizontal amplifier of the oscilloscope to the "OUT PUT SELECTOR" switch or to "HORIZ. INPUT" binding posts.
10	VERT. SCOPE INPUT - EXT. INT. (switch)	Connects the vertical amplifier of the oscilloscope to the "OUT PUT SELECTOR" switch or to the "VERT. INPUT" binding posts.
11	INTENSITY(control)	Varies the brightness of the image on the cathode ray tube screen.
12	FOCUS (control)	Adjusts the focus of the electron beam on the cathode ray tube screen.
13	HORIZ. GAIN (control)	Adjusts the voltage admittet to the amplifier for the horizontal plates in the cathode ray tube.
14	VERT. GAIN (control)	Adjusts the voltage admitted to the amplifier for the vertical plates in the cathode ray tube.
15	HORIZ. INPUT (terminals)	Horizontal input terminals.
16	VERT. INPUT (terminals)	Vertical Input terminals.

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	Designation	Function
17	PRESS FOR - Δ F (switch)	Lowers the frequency of the 100 kc oscillator approximately one cycle per second.
18	FREQ. ADJ. (screwdriver adjustment)	See Section IV on "Standardization with WWV" for the use of this control.
19	FUSE (fuseholder located on the back of the chassis)	Contains a 1.6 ampere (slo-blo) cartridge fuse, replaced by unscrewing the fuseholder cap and inserting a new fuse.
20	Power Cable	The power cable consists of three conductors, two of which carry power to the instrument while the third conductor (green wire) is connected to the instrument chassis. The third wire projects from the cable near the plug end of the cable and may be connected to a ground when it is desirable to have a grounded instrument chassis.

2-6 OPERATION

To place the Model 100D Low Frequency Standard into operation, proceed as follows:

a. Connect instrument to 115-volt a-c power source and turn on power switch. See CAUTION with regard to crystal oven heating.

b. Set the front panel controls as follows:

ALL FREQUENCIES	Set to ALL FREQUENCIES
OUTPUT WAVE	Set to SINE
OUTPUT SELECTOR	Set to desired frequency
OUTPUT	Connect to equipment under test.

c. The frequency standard is now producing the desired sine wave frequency which may be obtained from either the front panel or rear chassis terminals. If only the 100 kc and 10 kc standard frequencies are to be used, the ALL FREQUENCIES switch may be set to 10 KC and 100 KC ONLY position for greatest clarity of the higher frequency signals, particularly when using the standard to obtain beat-frequency signals.

d. If high harmonic content is required in the standard output frequencies, the OUTPUT WAVE switch should be switched to RECT.

e. To operate the front panel cathode ray tube to check the division ratio of the internal frequency dividers, set the front panel controls as follows:

HORIZ. SCOPE INPUT	Set to INT.
VERT. SCOPE INPUT	Set to INT.
BEAM ON	Set to ON
INTENSITY	Increase for adequate brightness of trace
FOCUS	Adjust for sharp trace
HORIZ. GAIN	Adjust for convenient pattern
VERT. GAIN	Adjust for convenient pattern

f. The cathode ray tube will now indicate the division ratio of the frequency divider producing the frequency selected by the OUTPUT SELECTOR switch. If the 100 kc oscillator is known to be "on frequency" and each subsequent lower frequency shows a 1:10 pattern, all lower frequencies are also "on frequency". For information on reading Lissajous figures from the cathode ray tube, see paragraph 2-7.

g. If marker pips are required, connect the external equipment to the TIMING PIPS terminals. If all three timing pips are required, the ALL FREQUENCIES switch must be in the ALL FREQUENCIES position. If only the 100 μsec pips are desired, the ALL FREQUENCIES switch should be in the 10 KC and 100 KC ONLY position.

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2-7 USING THE FRONT PANEL CATHODE RAY TUBE FOR FREQUENCY MEASUREMENT

Low frequencies are very conveniently measured by means of Lissajous figures on an oscilloscope. Lissajous figures are produced on the screen of cathode ray tube when an alternating current voltage is connected to both the horizontal and vertical deflecting plates of the tube. When a standard frequency voltage is fed to one set of plates and a voltage of unknown frequency is connected to the other set, the resultant figure identifies the ratio between the standard and unknown frequencies. Figure 2-1 shows examples of simple Lissajous figures.

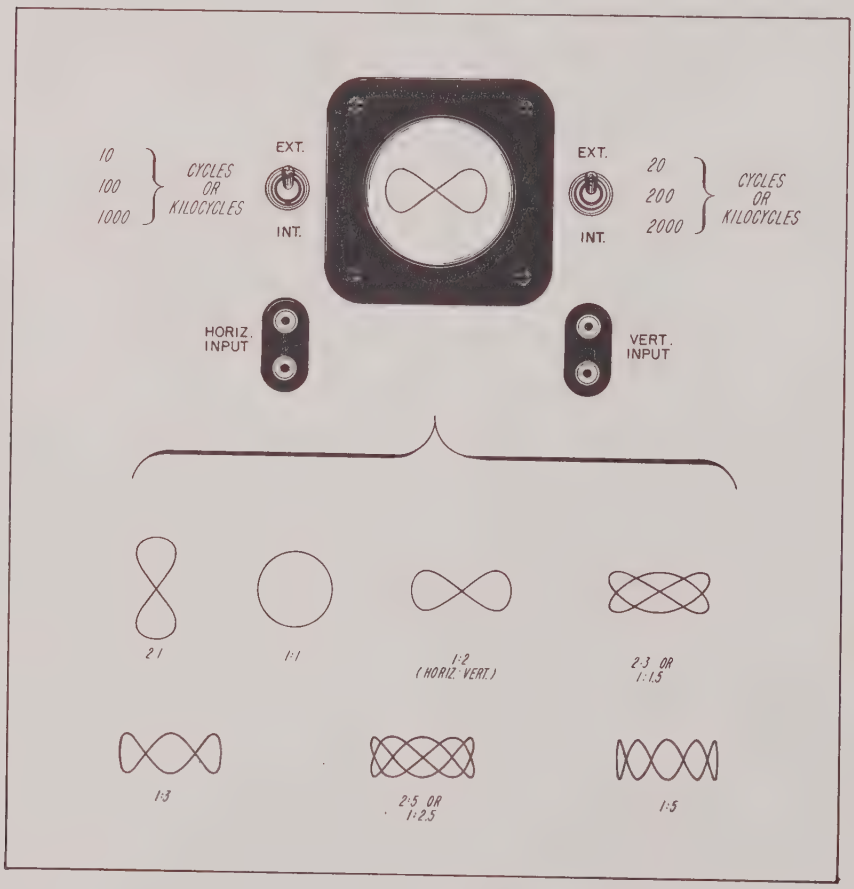

Fig. 2-1 Model 100D Oscilloscope Controls and Lissajous Patterns at Various Frequencies

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An external oscillator can be used to advantage to increase the ease of identification of the more complex patterns. For example, when measuring "inconvenient" frequencies such as 210 cps, the oscillator can be adjusted to 200 cps against the 100 cps output of the standard, resulting in a simple figure-eight pattern on the oscilloscope. By then switching the standard to 10 cps and adjusting the oscillator to the first frequency above 200 cps that results in a sinusoidal pattern, a frequency of 210 cps can be accurately obtained on the oscillator. The oscillator frequency is then compared with the unknown frequency.

2-8 CHECKING AND ADJUSTING THE 100 KC STANDARD OSCILLATOR

The 100 kc oscillator circuit of the Model 100D is set exactly at 100 kc at the Hewlett-Packard factory. This degree of accuracy is sufficient for most purposes; however, to obtain the best accuracy of which the crystal stability justifies, the oscillator should be checked with a primary frequency standard at frequent intervals (once per week).

The most accessible primary frequency standard is the standard frequencies broadcast by the National Bureau of Standards Station WWV at Washington, D.C. Station WWV broadcasts standard frequencies twenty-four hours a day on the following frequencies: 2.5, 5, 10, 15, 20, 25, 30 and 35 megacycles. For more detailed information on this service a Bureau of Standards circular, "Methods of Using Standard Frequencies Broadcast by Radio", may be purchased from the Superintendant of Documents, Government Printing Office, Washington, D.C.

The simplest method of checking the standard output frequencies from the 100D with radio station WWV is to beat a harmonic of either the rectangular 10 kc output wave, or of the 100 μsec timing pips, with the lowest possible frequency broadcast by WWV (2.5 mc when possible). The mixing of the two signals can be accomplished simply by wrapping a test lead connected to the 100D output terminals, around the antenna of the receiver used to receive WWV. This method is successful and straightforward when the signal strength from WWV is high. If the signal strength is low, or the low frequencies are not receivable, the 100 kc signal from the 100D must be multiplied to lowest frequency from WWV that is receivable. To obtain successful mixing at the receiver antenna, it is best if the two signals are similar in strength, and the receiver is not partially blocked by any r-f energy that is received. To set the 100 kc oscillator "on frequency", adjust the FREQ. ADJ. screwdriver control on the front panel to exactly zero-beat the 100D signal with that from WWV. No further adjustment is necessary. Each lower frequency is obtained from 10:1 frequency divider

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which cannot introduce "small" errors in frequency, but can only divide by the correct number, or an incorrect number if sufficiently far out of adjustment. To adjust each frequency divider to the correct division ratio, first observe the ratio of each divider starting with the highest frequency and proceed as follows:

a. Remove 100D from cabinet.

b. With instrument operating, set the controls as follows:

OUTPUT SELECTOR	set to 10 kc
HORIZ. SCOPE INPUT	set to INT
VERT. SCOPE INPUT	set to INT
BEAM	set to ON

Adjust the INTENSITY, FOCUS and GAIN controls for most readable Lissajous pattern. Refer to paragraph 2-7 for information on how to read Lissajous figures for the purpose of determining frequency.

c. If the figure thus obtained on the cathode ray tube indicates a nine to one division ratio, adjust the left hand potentiometer marked 10 kc divider until a ten to one figure is obtained.

d. Repeat above steps with the OUTPUT SELECTOR in the 1 KC, 100 ~ and 10 ~ positions.

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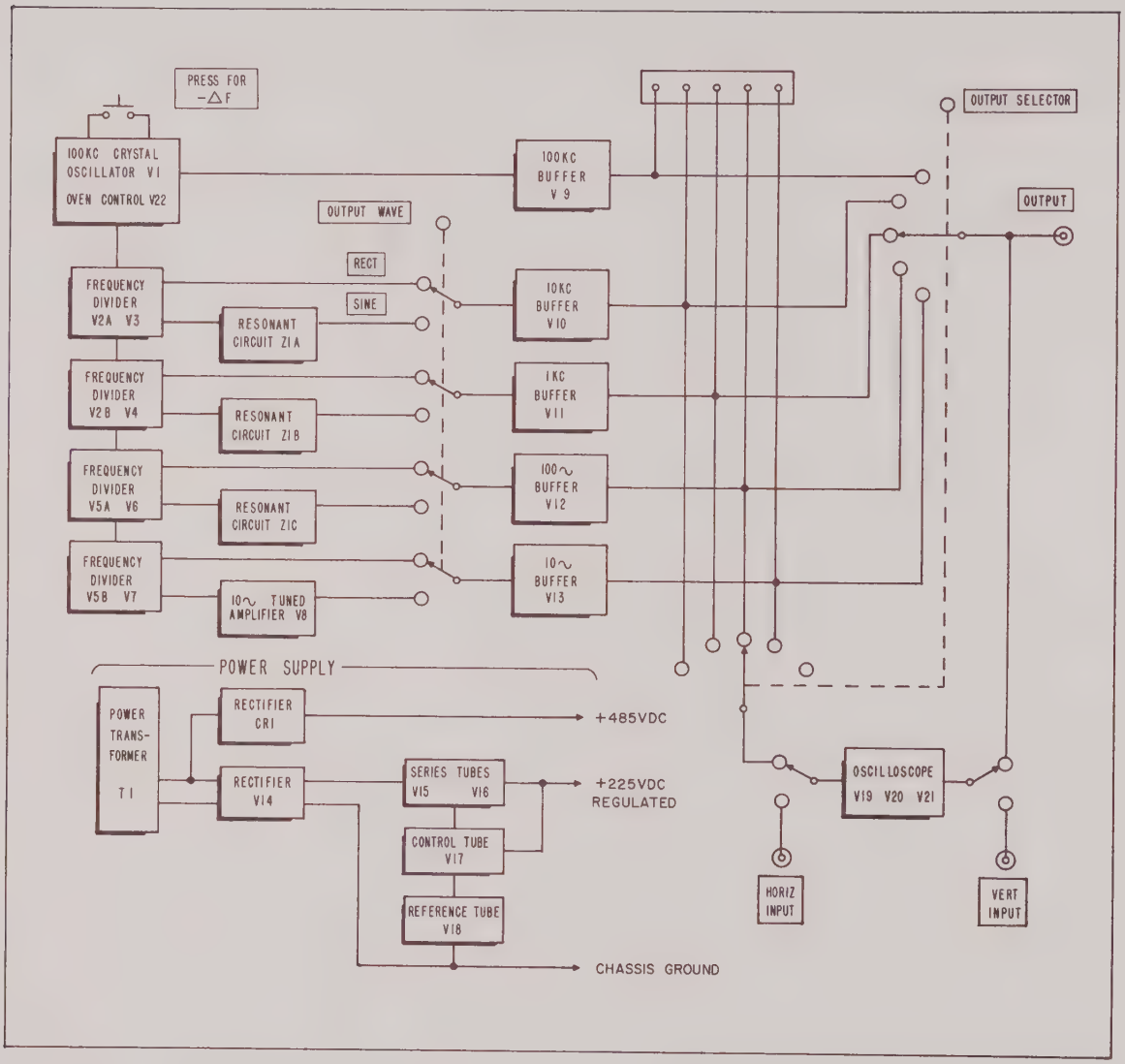

Fig. 3-1 Block diagram of -hp- Model 100D

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SECTION III

THEORY OF OPERATION

3-1 GENERAL CIRCUIT OPERATION

The hp Model 100D Low Frequency Standard consists of the stages shown in the block diagram in Figure 3-1. A crystal-controlled oscillator operating at 100 kilocycles controls the stability of all frequencies generated by the instrument. The frequencies of 10 kc, 1 kc, 100 cps and 10 cps are obtained from four 10:1 cascaded frequency dividers driven by the 100 kc oscillator. The oscillator and each divider are followed by separate output buffer tubes to provide low impedance at the output terminals. Rectangular waves are provided from the dividers for the four lower standard frequencies. Sine wave output is provided for all standard output frequencies by the use of suitable tuned circuits in parallel with the output waveform.

The cathode ray oscilloscope includes vertical and horizontal amplifiers which can be switched to receive either internally or externally generated signals for frequency comparison.

The power supply, which for simplicity is not shown in the block diagram, supplies electronically regulated voltage to all tubes in the frequency standard except the unregulated high voltage applied to the cathode ray tube.

3-2 100 KC OSCILLATOR CIRCUIT

The basic 100 kc signal for the 100D is generated by a modified Pierce oscillator using a very low temperature coefficient crystal. Housing for the crystal is a double-chamber oven, temperature controlled by a mercury thermostat having a temperature differential of 0.1° C. Control of the oven and stability of the crystal are such that an overall accuracy within 2 parts/million is obtainable over a period of one week. The crystal used in each 100D has been aged for a period of 30 days and is selected for stability prior to leaving the factory.

The 100 kc oscillator circuit is provided with several tuning adjustments, altogether providing not more than a few cycles variation in the crystal frequency. The two main tuning capacitors, C2 and C4, are used to make the initial frequency setting while the front panel adjustment, C1, is set midway. Small subsequent adjustments may then be made without changing C2 and C4. C59 is only in the circuit when the front panel pushbutton - F is pressed and shifts the oscillator frequency down approximately 1 cycle.

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The plate circuit of the oscillator tuned for maximum output from the oscillator by screwdriver adjustment L1.

3-3 FREQUENCY DIVIDER CIRCUIT

The signal from the 100 kc oscillator is fed to a series of four 10:1 phantastron frequency dividers. Each frequency divider operates in the same manner; the circuits differ only in component values to handle the various frequencies. Each divider is coupled to the previous stage by a biased diode which allows only negative pulses above a predetermined level to trigger the divider. The actual frequency divider tube operates as a controlled one-shot multivibrator. The circuit values are selected to produce a pulse that lasts through nine cycles of an input frequency to be divided. After the one-shot multivibrator has been triggered, it will not respond to the next nine cycles, then is retriggered on the tenth cycle, thus producing one output pulse for every ten input cycles. It is possible, by increasing or decreasing the input bias to retrigger the multivibrator one cycle too soon or too late and obtain a 9:1 or 11:1 division.

Assuming for a moment that the oscillator is not operating, the operation of the circuit can be described as follows: in a quiescent state tube V3 operates in such a manner that the plate is at a higher voltage than the screen grid, but draws no current. This is explained by the fact that the suppressor grid is sufficiently negative with respect to the cathode to cut off the plate current. Therefore, the screen grid acts as a plate for the space current. The control grid is at cathode potential and thus, the screen grid is drawing heavy current. The cathode of the diode V2 is connected to a lower dc voltage than its plate so that V2 is a closed circuit to small negative voltages applied to its cathode. The negative portion of the oscillator signal is large enough to pass through diode V2 and trigger a multivibrator action in V3. The negative voltage is passed from the plate of V3 to the control grid through C9. The negative control grid reduces the space current, causing the screen voltage to rise and the cathode voltage to fall. This action reduces the suppressor bias with respect to the cathode sufficiently that the current passes through the suppressor grid to the plate. The plate voltage therefore drops rapidly, reinforcing the original negative voltage on the control grid. Because the plate voltage on V3 is now low, the plate of V2 is at a lower voltage than its cathode and no negative trigger voltages can pass through diode V2.

The circuit remains in this condition as the negative charge on the coupling capacitor C9 leaks off through resistor R12. As the grid voltage slowly rises, the space current in the tube slowly increases, causing the plate voltage to drop somewhat more. At the same time, the cathode voltage rises, increasing the bias on the suppressor grid. Finally, a critical point is reached where the screen has more attraction for the space current than the plate.

When this critical point is reached, the second portion of the multivibrator action occurs: the screen voltage falls rapidly and plate current ceases. This action transfers a positive voltage to the control grid, resulting in more space current and reinforcing the drop in screen voltage. The circuit then becomes quiescent and is prepared for the next negative pulse through diode V2. The time constants in the circuit are adjusted so that the total multivibrator action requires slightly more than nine cycles of the oscillator frequency, the circuit being again ready for triggering on the tenth cycle. Thus, a frequency-dividing action has occured.

3-4 RECTANGULAR AND SINE OUTPUT WAVEFORMS

For rectangular output waveform the signal is obtained from the cathode of each of the frequency dividers without compensation or filtering. The signal is fed through the buffer stage to the output terminals. This type waveform is not obtainable at 100 kc since the signal is obtained from the crystal oscillator.

For sinusoidal output, the signal is obtained from the screen grid of each frequency divider through an isolating network and a parallel resonant circuit that is fixed tuned at the factory. The signal from the tuned circuit is applied to the buffer tube and to the output terminals. This sinusoidal wave is relatively harmonic-free, having less than 4% distortion.

To obtain sinusoidal output from the 10 cycles divider, a low pass rc filter and an amplifier stage containing controlled negative feedback, are utilized in place of the inductance-capacity circuits used at the higher frequencies. The 10-cycle rectangular wave is applied through a low-pass rc filter to the grid of V8. The signal at the plate of V8 is coupled through a high pass filter back to the grid, cancelling the harmonics of the fundamental of the rectangular wave. The low-distortion sine wave produced at the plate is then coupled to the buffer stage and to the output terminals.

3-5 TIMING PIPS

The timing pips are produced by combining the rectangular outputs of all frequency dividers, except the 10-cycle divider, through very small coupling capacitors and clipping the negative portion of the resultant multiple waveform with a crystal diode. The resulting wave is a sharp, positive spike corresponding to the leading edge of the rectangular waves from the frequency dividers.

3-6 POWER SUPPLY

The power supply consists of a power transformer with a single high-voltage winding feeding a full wave rectifier and electronic voltage regulator supplying +225 volts dc to all the circuits of the frequency standard. The voltage regulator circuit maintains constant output voltage with wide changes in load current and line voltage. The same winding on the transformer also supplies a half-wave metallic rectifier and rc filter for operating the cathode ray tube.

V15, V16, V17 and V18 constitute the voltage regulator circuit. V18 is a constant-voltage tube which provides the reference bias for V17. V15 and V16 in parallel operate as a series tube, or variable resistor, controlled by the voltage at the grid of V17. If the regulated B+ at the cathode of V15 and V16 tends to increase, the grid voltage of V17 tends to increase, causing V17 to draw more current. This lowers the plate voltage of V17 and therefore the grid voltage of V15 and V16, resulting in greater plate resistance for V15 and V16. The greater plate resistance causes a greater voltage drop across V15 and V16, compensating for the increased voltage at its cathode and resulting in a substantially constant voltage output.

If the regulated B+ voltage tends to decrease, the reverse of the above action occurs, also tending to maintain the cathode voltage substantially constant. Ripple in the output voltage is coupled to the grid of V17 by capacitor C49. Variations in the dc voltage are coupled to the grid of V17 through the voltage divider R80, R81 and R82. The bias for V17 and the level of the output voltage from V15 and V16 are determined by the setting of R80.

3-7 CRYSTAL OVEN HEATER OPERATION

The heating element inside the crystal oven is operated through relay REL1 on 6.3-volt ac power. Relay REL1 is normally open and is closed by the normal plate current through V22. V22 normally draws sufficient current to close the relay to heat the oven. When the oven is up to temperature the thermostatic closes and connects the control grid of V22 to ground, thus biasing the tube to cutoff and opening the relay. The cycle repeats itself such that the oven temperature is maintained within .1° C.

SECTION IV

SERVICE INSTRUCTIONS

4-1 TUBE REPLACEMENT AND ADJUSTMENTS

The following chart lists the electron tubes used in the 100D and indicates which tubes are critical and require adjustments following replacement. Detailed instructions on making the adjustments are included in subsequent paragraphs.

Tube	Type	Function	Adjustments Required
V1	6BH6	100 kc oscillator	Adjust C1 to bring "on frequency" Adjust C5 to peak output amplitude
V2	6AL5	Coupling diodes	Adjust R6 for 10:1 division Adjust R14 for 10:1 division
V3	6AS6	10 kc divider	Adjust R6 for 10:1 frequency division
V4	6AS6	1 kc divider	Adjust R14 for 10:1 frequency division
V5	6AL5	Coupling diodes	Adjust R23 for 10:1 division Adjust R32 for 10:1 division
V6	6AS6	100 cycle divider	Adjust R23 for 10:1 division
V7	6AS6	10 cycle divider	Adjust R32 for 10:1 division
V8	6BH6	10 cycle amplifier	No adjustments required
V9 V10 V11 V12 V13	6AH6	Buffers	No adjustments required

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Tube	Type	Function	Adjustments Required
V14	5R4GY	Rectifier Series	No adjustments required
V15 V16	6L6GA	Regulators	Adjust R81 to obtain +225 volts at pin 8, cathode
V17	6AV6	Control tube	See V15
V18	OA2	Reference tube	See V15
V19	2AP1A	Cathode ray tube	No adjustments required
V20 V21	6BH6	Oscilloscope amplifiers	No adjustments required

4-2 ADJUSTING THE FREQUENCY DIVIDERS

The division ratio of each frequency divider is adjustable from approximately a 9:1 ratio to an 11:1 ratio by a screwdriver adjusted potentiometer just inside the front panel. The proper division ratio is observed by switching the front panel cathode ray tube for internal measurements and adjusting each of the dividers to obtain a 10:1 Lissajous figure. (See paragraph 2-7).

The cathode ray tube automatically shows the division ratio of the divider selected by the OUTPUT SELECTOR switch. To adjust the 10 kc divider set the OUTPUT SELECTOR to 10 KC, note pattern on cathode ray tube, and if necessary, adjust the potentiometer labelled 10 KC DIVIDER to obtain a 10:1 pattern. Repeat adjustment for each other divider, starting always with the 10 kc divider. When making the divider adjustment, it will be noticed that the correct division ratio may be obtained over a wide range of the adjusting potentiometer; set the potentiometer to the center of this range. If it is not possible to adjust a divider to obtain a 10:1 ratio, the trouble lies in the tube selected or in a faulty component in that particular circuit.

4-3 ADJUSTING THE REGULATED POWER SUPPLY OUTPUT VOLTAGE

Following replacement of any tube within the regulated power supply, the dc output voltage at the cathode (pin 8) of V15 or V16 must be

measured from chassis ground and if necessary, set to be exactly +225 volts by adjustment of R81. The output voltage should remain stable with line voltage variations between ±10% of 115 volts.

4-4 ADJUSTING THE 100 KC OSCILLATOR

Following replacement of V1 it is desirable although not necessary to check the frequency and output from the crystal oscillator. Small changes in output frequency (several cycles) may be made by adjustment of C1 or by simultaneously adjusting both C2 and C4; C2 and C4 must retain approximately equal settings. No further control of the output frequency is possible.

Peaking the output from the crystal oscillator is accomplished by measuring the 100 kc standard output frequency with a reliable ac voltmeter and adjusting L1 (inside the shield and accessible from the bottom of the chassis).

4-5 CRYSTAL OVEN DISASSEMBLY

The following is the step-by-step procedure necessary to disassemble the crystal oven to the point that the heater and socket connections are exposed. Refer to Figure 4-1 and proceed as follows:

1. Remove the four wing nuts (1), the cover, and the insulating pad inside the cover.
2. Remove the four spade bolts that hold the cover and the ring on top of the oven.
3. Remove the two nuts (2) holding the thermometer, then the thermometer.
4. Disconnect the thermostat wires from terminals(3).
5. Remove the two mounting screws (4) and the thermostat guard. Draw out the thermostatic switch (5).
6. Remove the four screws (6) at the bottom edge of the oven and slide clamp (7) off of the housing. The housing will unwrap from around the bottom of the casting.
7. Unwrap the insulation until the heat wires and socket are exposed.

4-6 230-VOLT OPERATION

The 100D may be connected for use on 230-volt lines by changing the connections on the primaries of the two transformers in the instrument. Electrically, the change consists of connecting the dual primary windings of the two power transformers in series instead of in parallel. Phasing of the windings is automatically taken care of if the directions are followed carefully. The primaries of the two transformers are connected in parallel and are changed simultaneously for 230-volt operation as follows:

a. Refer to the transformer detail on the schematic diagram. Check all wiring changes carefully.

b. Cut the wire jumper that connects the Black-Green wires and the Black wires together.

c. Cut the wire jumper that connects the Black-Red wires and the Black-Yellow wires together.

d. Connect a wire lead from the Black-Green pair to the Black-Yellow pair.

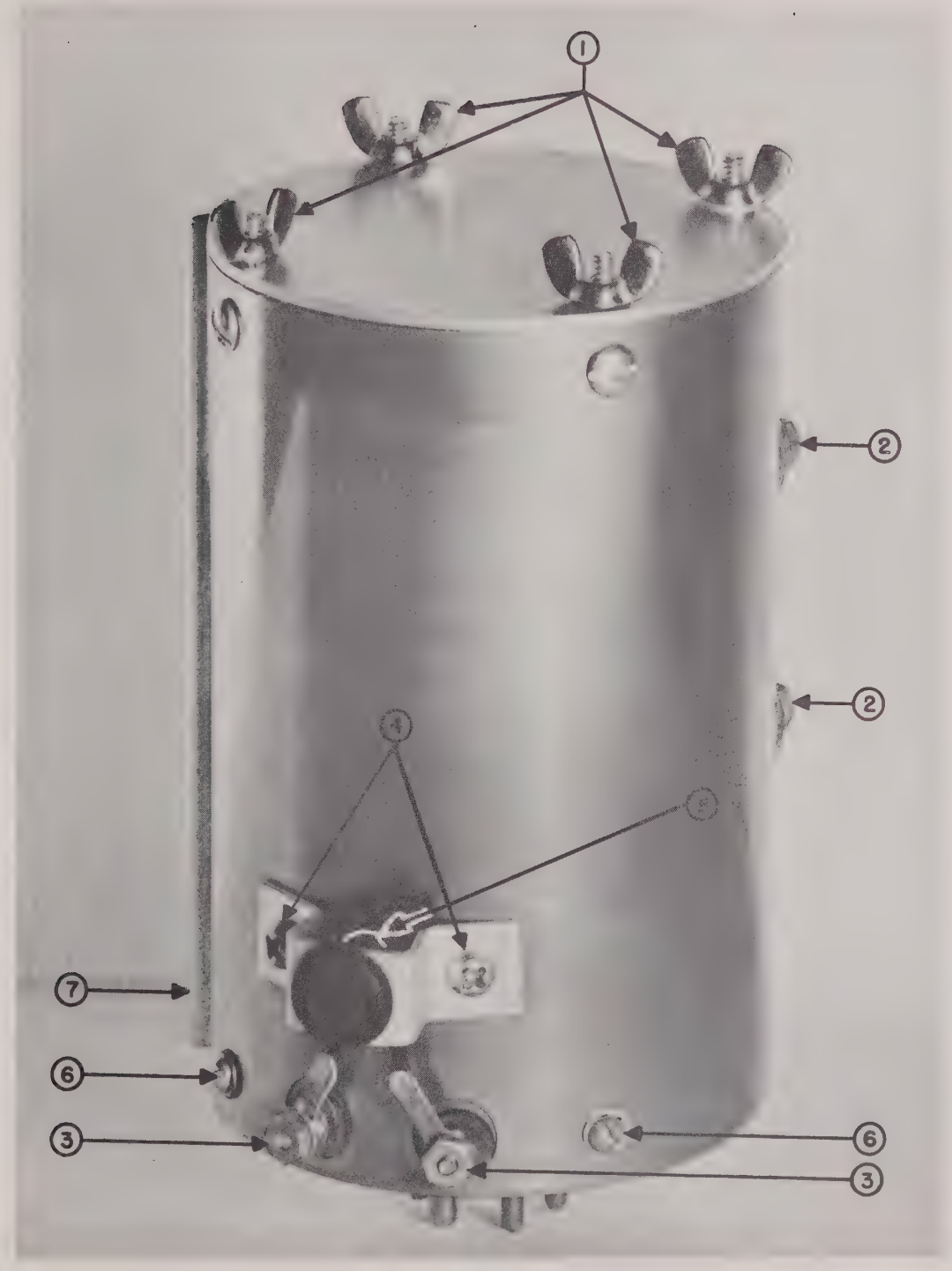

Fig. 4-1 Crystal Oven Assembly

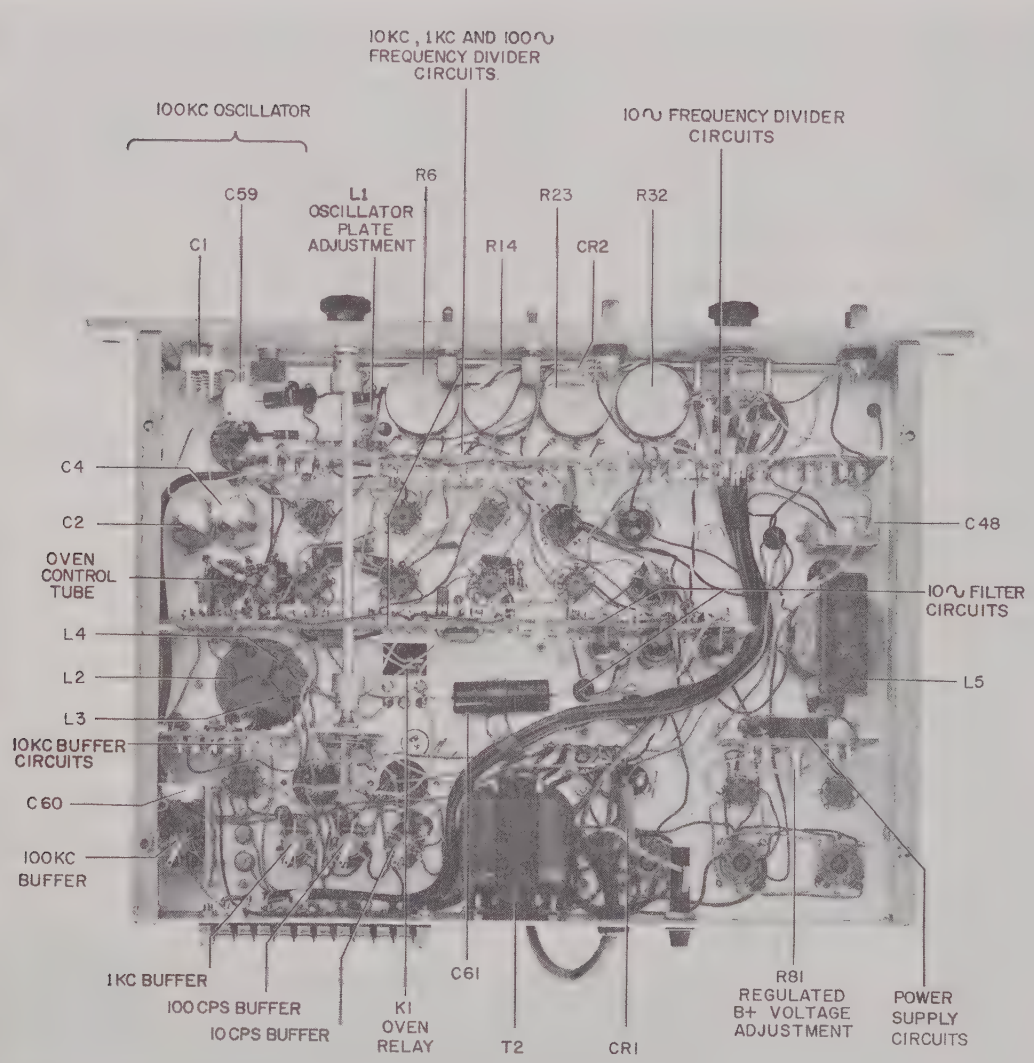

Fig. 4-2 Model 100D Bottom View

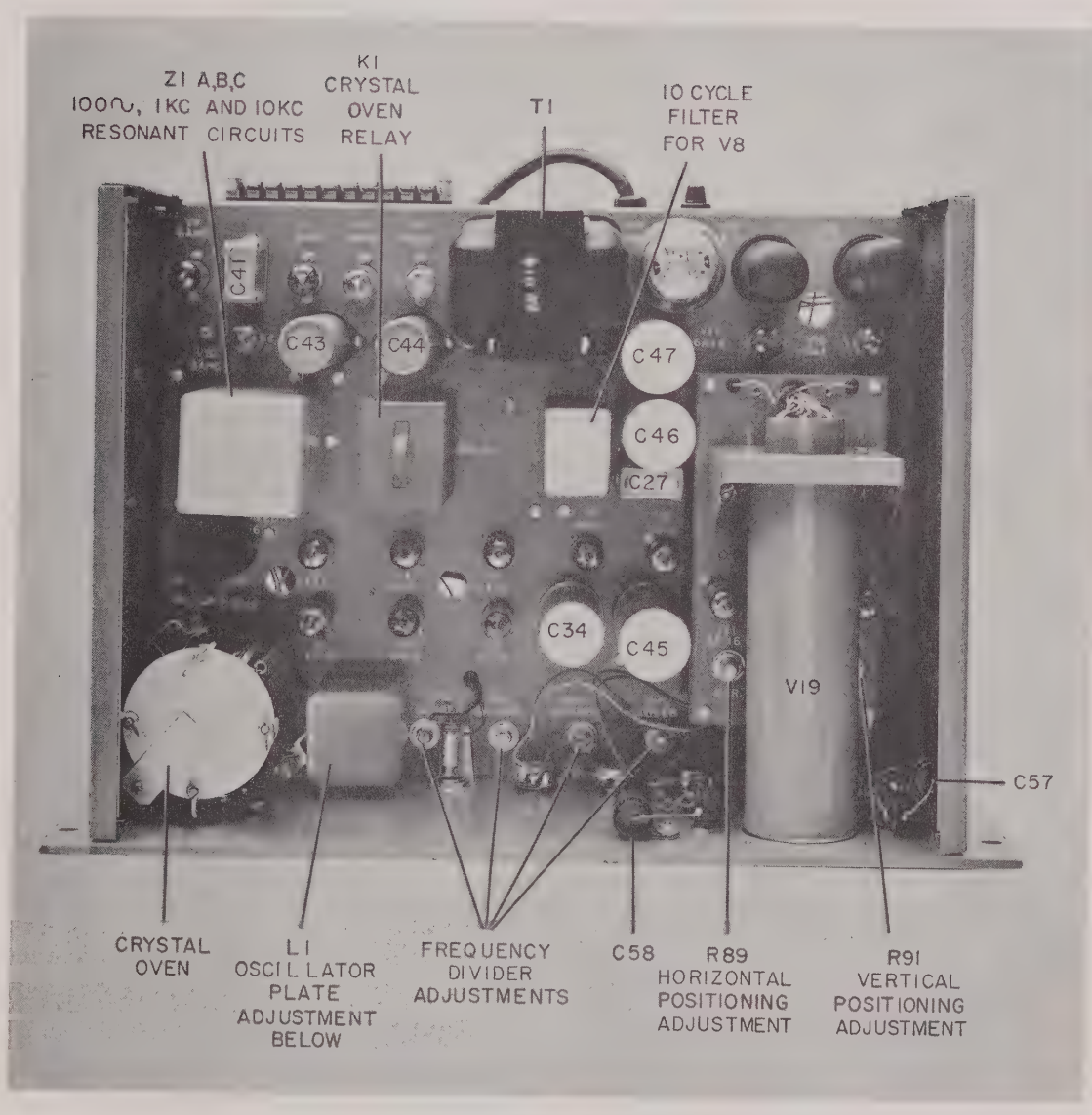

Fig. 4-3 Model 100D Top View

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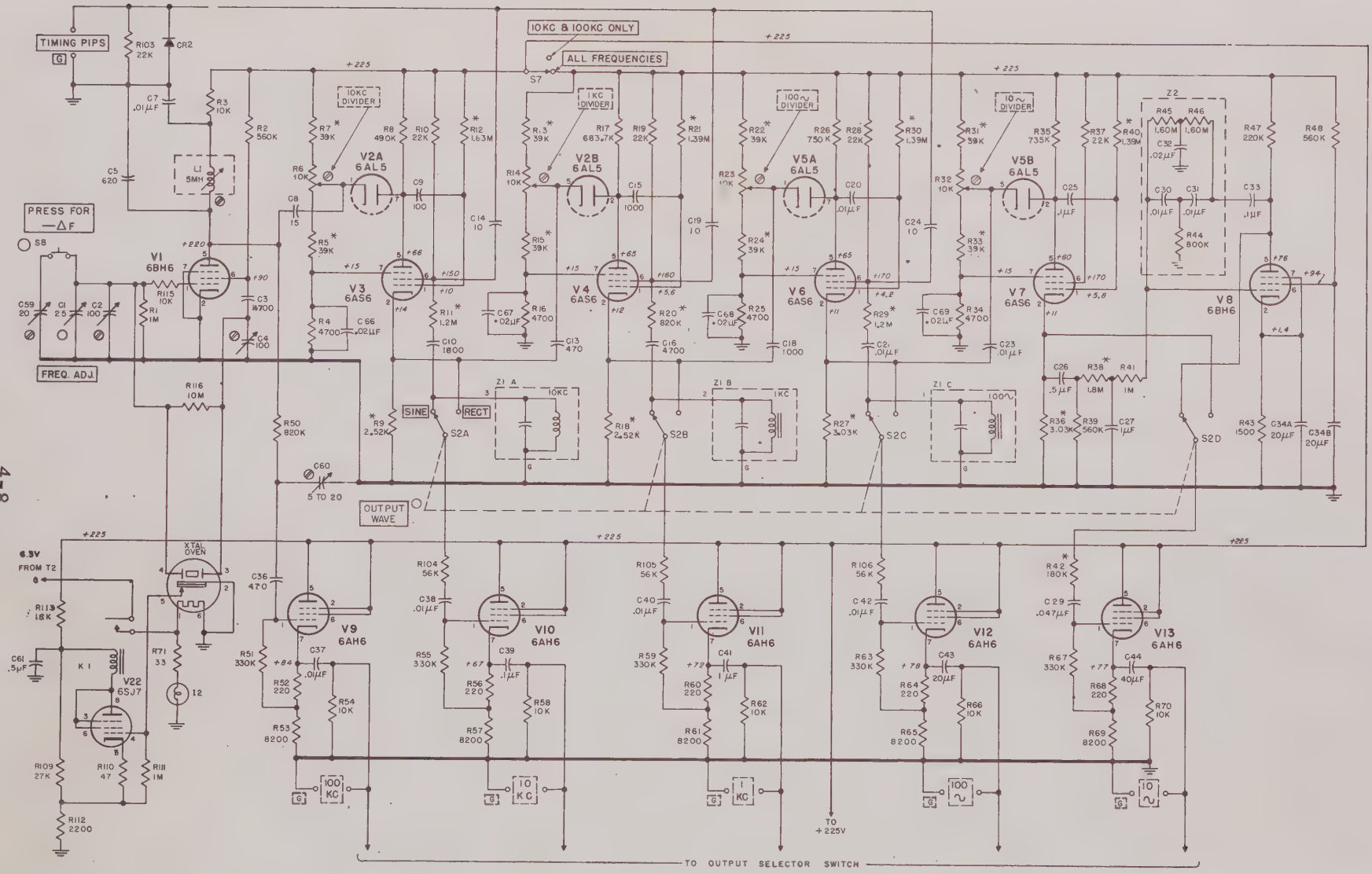

FIGURE 4-4 OSCILLATOR AND DIVIDER SECTION

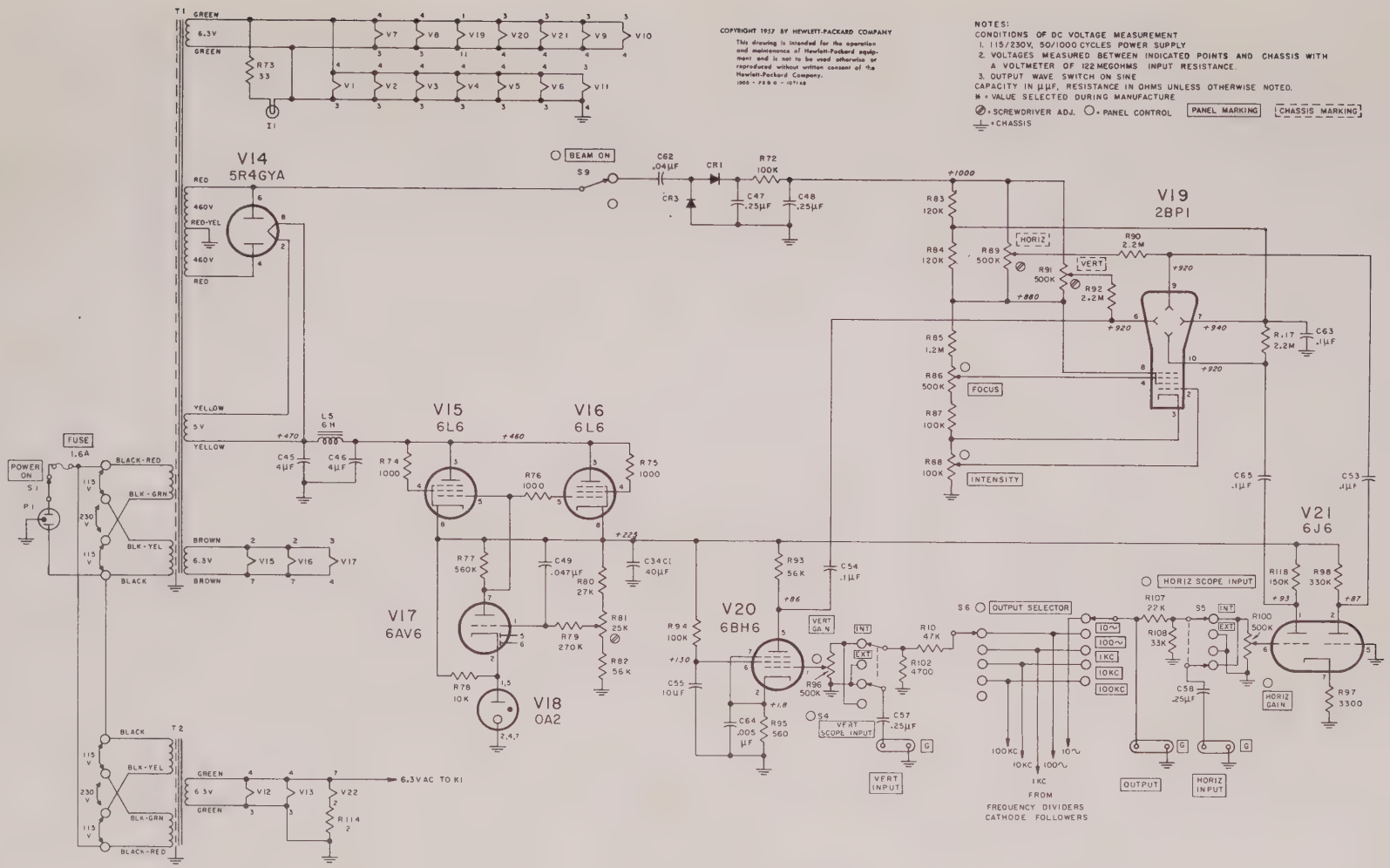

FIGURE 4-5 POWER SUPPLY AND OSCILLOSCOPE

SECTION V
TABLE OF REPLACEABLE PARTS

NOTE

Readily available standard-components have been used in this instrument, whenever possible. However, special components may be obtained from your local Hewlett-Packard representative or from the factory.

When ordering parts always include:

1. ℗ Stock Number.
2. Complete description of part including circuit reference.
3. Model number and serial number of instrument.
4. If part is not listed give complete description, function, and location of part.

If there are any corrections for the Table of Replaceable Parts they will be listed on an Instruction Manual Change sheet at the front of this manual.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	℗ STOCK NO.	#			
C1	Capacitor: variable, air dielectric, 3.6 μμf to 26 μμf All Star	12-9	1			
C2	Capacitor: variable, air dielectric, 7.5 μμf to 102.7 μμf AA*	12-17	2			
C3	Capacitor: fixed, mica, 4700 μμf, ±10%, 500 vdcw V*	14-44	2			
C4	Same as C2					
C5	Capacitor: fixed, silver mica, 620 μμf, ±5%, 500 vdcw A*	15-12	1			
C6	This circuit reference not assigned.					
C7	Capacitor: fixed, paper dielectric, .01 μf, ±10%, 600 vdcw CC*	16-11	6			
C8	Capacitor: fixed, mica, 15 μμf, ±10%, 500 vdcw V*	14-15	1			
C9	Capacitor: fixed, mica, 100 μμf, ±5%, 300 vdcw V*	14-76	1			
C10	Capacitor: fixed, mica, 1800 μμf, ±10%, 500 vdcw Z*	14-47	1			
C11	This circuit reference not assigned.					
C12	Part of Z1 (not separately replaceable)					
C13	Capacitor: fixed, mica, 470 μμf, ±10%, 500 vdcw V*	14-62	1			
C14	Capacitor: fixed, mica, 10 μμf, ±10%, 500 vdcw V*	14-10	4			
C15	Capacitor: fixed, silver mica, .001 μf, ±5%, 500 vdcw A*	15-57	1			
C16	Same as C3					
C17	Part of Z1 (not separately replaceable)					
C18	Capacitor: fixed, mica, 1000 μμf, ±10%, 500 vdcw V*	14-11	1			
C19	Same as C14					
C20	Capacitor: fixed, silver mica, .01 μf, ±1%, 300 vdcw A*	15-41	1			
C21	Capacitor: fixed, mica, .01 μf, ±10%, 300 vdcw V*	14-23	1			
C22	Part of Z1 (not separately replaceable)					
C23	Same as C7					
C24	Same as C14					

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	℗ STOCK NO.	#			
C25	Capacitor: fixed, paper dielectric, .1 µf, ±5%, 600 vdcw CC*	16-54	1			
C26	Capacitor: fixed, paper dielectric, 0.5 µf, ±10%, 200 vdcw CC*	16-37	1			
C27	Capacitor: fixed, paper dielectric, 1 µf, ±10%, 600 vdcw Z*	17-12	2			
C28	This circuit reference not assigned.					
C29	Capacitor: fixed, paper dielectric, .047 µf, ±10%, 600 vdcw CC*	16-15	2			
C30, 31	Capacitor: fixed, mica, .01 µf, ±1%, 300 vdcw, part of Z2 (not separately replaceable)					
C32	Two .02µf, ±1%, 300 vdcw capacitors connected in parallel, part of Z2 (not separately replaceable).					
C33	Capacitor: fixed, paper dielectric, .1 µf, ±10%, 600 vdcw CC*	16-1	2			
C34ABCD	Capacitor: fixed, electrolytic, 4 sections, 20 µf/sect., 450 vdcw CC*	18-42HP	1			
C35	This circuit reference not assigned.					
C36	Same as C13					
C37, 38	Same as C7					
C39	Same as C33					
C40	Same as C7					
C41	Same as C27					
C42	Same as C7					
C43	Capacitor: fixed, electrolytic, 20 µf, 450 vdcw CC*	18-20 HP	1			
C44	Capacitor: fixed, electrolytic, 40 µf, 450 vdcw CC*	18-40 HP	1			
C45, 46	Capacitor: fixed, paper, 4 µf, ±10%, 600 vdcw P*	17-10	2			
C47, 48	Capacitor: fixed, paper dielectric, .25 µf, ±10%, 1500 vdcw Z*	17-30	2			
C49	Same as C29					
C50, 51, 52	These circuit references not assigned.					
C53, 54	Capacitor: fixed, paper dielectric, .1 µf, ±10%, 1000 vdcw P*	16-6	4			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	℘ STOCK NO.	#
C55	Capacitor: fixed, electrolytic, 10 µf, ±50%, 450 vdcw X*	18-10	1
C56	This circuit reference not assigned.		
C57, 58	Capacitor: fixed, paper dielectric, .22 µf, ±10%, 400 vdcw CC*	16-48	2
C59, 60	Capacitor: variable, ceramic dielectric, 5 to 20 µµf, 500 vdcw L*	13-20	2
C61	Capacitor: fixed, paper dielectric, .5 µf, ±10%, 400 vdcw J*	16-58	1
C62	Capacitor: fixed, paper dielectric, .04 µf, ±20%, 1600 vdcw J*	16-76	1
C63	Same as C53		
C64	Capacitor: fixed, ceramic dielectric, .005 µf, 500 vdcw K*	15-47	1
C65	Same as C53		
C66, 67, 68, 69	Capacitor: fixed, ceramic disc., .02 µf, tol. -0% +100%, 600 vdcw CA*	15-85	4
CR1	Rectifier, selenium CM*	212-57	2
CR2	Diode, crystal BU*	212-G11A	1
CR3	Same as CR1		
F1	Fuse: 1.6 amp, slo-blo 115V E* Fuse: 0.8 amp, slo-blo 230V E*	211-15 211-57	1 1
I1, 2	Lamp, incandescent: 6-8V, .15 amp, #47 N*	211-47	2
K1	Relay, armature, dc Phillips Control	49-17	1
L1	Coil, R.F.: 5µh Western Coil	48-28	1
L2, 3, 4	These circuit references not assigned.		
L5	Reactor, filter: 6h, 240 ohms Paeco	911-12	1
P1	Power cord: Elec. Cords	812-56	1
R1	Resistor: fixed, composition, 1 megohm, ±10%, 1 W B*	24-1M	2
R2	Resistor: fixed, composition, 560,000 ohms, ±10%, 1 W B*	24-560K	4
R3	Resistor: fixed, composition, 10,000 ohms, ±10%, 1 W B*	24-10K	3
R4	Resistor: fixed, composition, 4700 ohms, ±10%, 1 W B*	24-4700	5

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	℗ STOCK NO.	#
R5	Resistor: fixed, composition, 39,000 ohms, ±10%, 1 W, Electrical value adjusted at factory. B*	24-39K	8
R6	Resistor: variable, linear taper, 10,000 ohms, ±10% B*	210-35	4
R7	Same as R5		
R8	Resistor: fixed, deposited carbon, 490,000 ohms, ±1%, 1 W NN*	31-490K	1
R9	Resistor: fixed, deposited carbon, 2.52K ohms, ±1%, 1 W, Electrical value adjusted at factory. NN*	31-2.52K	2
R10	Resistor: fixed, composition, 22,000 ohms, ±10%, 2 W B*	25-22K	4
R11	Resistor: fixed, composition, 1.8 megohms, ±10%, 1 W, Electrical value adjusted at factory. B*	24-1.8M	2
R12	Resistor: fixed, deposited carbon, 1.39 megohms, ±1%, 1 W, Electrical value adjusted at factory. NN*	31-1.39M	4
R13	Same as R5		
R14	Same as R6		
R15	Same as R5		
R16	Same as R4		
R17	Resistor: fixed, deposited carbon, 683.7K ohms, ±1%, 1 W NN*	31-683.7K	1
R18	Same as R9		
R19	Same as R10		
R20	Resistor: fixed, composition, 820,000 ohms, ±10%, 1 W, Electrical value adjusted at factory. B*	24-820K	2
R21	Same as R12		
R22	Same as R5		
R23	Same as R6		
R24	Same as R5		
R25	Same as R4		
R26	Resistor: fixed, deposited carbon, 750,000 ohms, ±1%, 1 W NN*	31-750K	1

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION	℗ STOCK NO.	#			
R27	Resistor: fixed, deposited carbon, 3.03K ohms, ±1%, 1 W, Electrical value adjusted at factory. NN*	31-3.03K	2			
R28	Same as R10					
R29	Resistor: fixed, composition, 2.2 megohms, ±10%, 1 W, Electrical value adjusted at factory. B*	24-2.2M	1			
R30	Same as R12					
R31	Same as R5					
R32	Same as R6					
R33	Same as R5					
R34	Same as R4					
R35	Resistor: fixed, deposited carbon, 735,000 ohms, ±1%, 1 W NN*	31-735K	1			
R36	Same as R27					
R37	Same as R10					
R38	Same as R11					
R39	Same as R2					
R40	Same as R12					
R41	Same as R1					
R42	Resistor: fixed, composition, 180,000 ohms, ±10%, 1 W, Electrical value adjusted at factory. B*	24-180K	1			
R43	Resistor: fixed, composition, 1500 ohms, ±10%, 1 W B*	24-1500	1			
R44	Resistor: fixed, deposited carbon, 800,000 ohms, ±1%, 1 W, part of Z2 (not separately replaceable)					
R45, 46	Two 3.05 megohms and two 3.28 megohm resistors in parallel selected to be 1.59 - 1.60 megohms, part of Z2 (not separately replaceable).					
R47	Resistor: fixed, composition, 220,000 ohms, ±10%, 1 W B*	24-220K	1			
R48	Same as R2					
R49	This circuit reference not assigned.					
R50	Same as R20					

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.	#			
R51	Resistor: fixed, composition, 330,000 ohms, ±10%, 1 W	B*	24-330K	6			
R52	Resistor: fixed, composition, 220 ohms, ±10%, 1 W	B*	24-220	5			
R53	Resistor: fixed, composition, 8200 ohms, ±10%, 2 W	B*	25-8200	5			
R54	Resistor: fixed, composition, 10,000 ohms, ±10%, 1/2 W	B*	23-10K	5			
R55	Same as R51						
R56	Same as R52						
R57	Same as R53						
R58	Same as R54						
R59	Same as R51						
R60	Same as R52						
R61	Same as R53						
R62	Same as R54						
R63	Same as R51						
R64	Same as R52						
R65	Same as R53						
R66	Same as R54						
R67	Same as R51						
R68	Same as R52						
R69	Same as R53						
R70	Same as R54						
R71	Resistor: fixed, composition, 33 ohms, ±10%, 1 W	B*	24-33	2			
R72	Resistor: fixed, composition, 100,000 ohms, ±10%, 1 W	B*	24-100K	3			
R73	Same as R71						
R74, 75, 76	Resistor: fixed, composition, 1000 ohms, ±10%, 1/2 W	B*	23-1000	3			
R77	Same as R2						
R78	Same as R3						

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.	#
R79	Resistor: fixed, composition, 270,000 ohms, ±10%, 1 W	B*	24-270K	1
R80	Resistor: fixed, composition, 27,000 ohms, ±10%, 1 W	B*	24-27K	1
R81	Resistor: variable, composition, 25,000 ohms, ±20%, 1 W	BO*	210-11	1
R82	Resistor: fixed, composition, 56,000 ohms, ±10%, 1 W	B*	24-56K	2
R83, 84	Resistor: fixed, composition, 120,000 ohms, ±10%, 1 W	B*	24-120K	1
R85	Resistor: fixed, composition, 1.2 megohms, ±10%, 1 W	B*	24-1.2M	1
R86	Resistor: variable, composition, linear taper, 500,000 ohms	G*	210-20	5
R87	Same as R72			
R88	Resistor: variable, composition, linear taper, 100,000 ohms,	G*	210-82	1
R89	Same as R86			
R90	Resistor: fixed, composition, 2.2 megohms, ±10%, 1 W	B*	24-2.2M	3
R91	Same as R86			
R92	Same as R90			
R93	Same as R82			
R94	Same as R72			
R95	Resistor: fixed, composition, 560 ohms, ±10%, 1 W	B*	24-560	1
R96	Same as R86			
R97	Resistor: fixed, composition, 3300 ohms, ±10%, 1 W	B*	24-3300	1
R98	Same as R51			
R99	This circuit reference not assigned.			
R100	Same as R86			
R101	Resistor: fixed, composition, 47,000 ohms, ±10%, 1 W	B*	24-47K	1
R102	Same as R4			
R103	Resistor: fixed, composition, 22,000 ohms, ±10%, 1/2 W	B*	23-22K	1

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.	#			
R104, 105, 106	Resistor: fixed, composition, 56,000 ohms, ±10%, 1/2 W	B*	23-56K	3			
R107	Resistor: fixed, composition, 22,000 ohms, ±10%, 1 W	B*	24-22K	1			
R108	Resistor: fixed, composition, 33,000 ohms, ±10%, 1 W	B*	24-33K	1			
R109	Resistor: fixed, composition, 27,000 ohms, ±10%, 2 W	B*	25-27K	1			
R110	Resistor: fixed, composition, 47 ohms, ±10%, 1/2 W	B*	23-47	1			
R111	Resistor: fixed, composition, 1 megohm, ±10%, 1/2 W	B*	23-1M	1			
R112	Resistor: fixed, composition, 2200 ohms, ±10%, 1 W	B*	24-2200	1			
R113	Resistor: fixed, composition, 18,000 ohms, ±10%, 2 W	B*	25-18K	1			
R114	Resistor: fixed, wirewound, 2 ohms, ±10%, 2 W	I*	26-30	1			
R115	Same as R3						
R116	Resistor: fixed, composition, 10 megohms, ±10%, 1/2 W	B*	23-10M	1			
R117	Same as R90						
R118	Resistor: fixed, composition, 150,000 ohms, ±10%, 1 W	B*	24-150K	1			
S1	Switch, toggle: SPST	D*	310-11	3			
S2	Switch, rotary	W*	310-73	1			
S3	This circuit reference not assigned.						
S4, 5	Switch toggle: DPDT	D*	310-54	2			
S6	Switch, rotary: output selector	W*	310-39	1			
S7	Same as S1						
S8	Switch, pushbutton	D*	310-75	1			
S9	Same as S1						
T1	Transformer, power	BS*	910-69	1			
T2	Transformer, power: filament	BS*	910-65	1			
V1	Tube, electron: 6BH6	ZZ*	212-6BH6	3			
V2	Tube, electron: 6AL5	ZZ*	212-6AL5	2			
V3, 4	Tube, electron: 5725	ZZ*	212-5725	4			

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

TABLE OF REPLACEABLE PARTS

CIRCUIT REF.	DESCRIPTION, MFR. * & MFR. DESIGNATION		℗ STOCK NO.	#
V5	Same as V2			
V6, 7	Same as V3			
V8	Same as V1			
V9, 10, 11, 12, 13	Tube, electron: 6AH6	ZZ*	212-6AH6	5
V14	Tube, electron: 5R4GY/A	ZZ*	212-5R4GY/A	1
V15, 16	Tube, electron: 6L6	ZZ*	212-6L6	2
V17	Tube, electron: 6AV6	ZZ*	212-6AV6	1
V18	Tube, electron: OA2	ZZ*	212-OA2	1
V19	Tube, electron: 2BP1	ZZ*	212-2BP1	1
V20	Same as V1			
V21	Tube, electron: 6J6	ZZ*	212-6J6	1
V22	Tube, electron: 6SJ7	ZZ*	212-6SJ7	1
Z1	Tuned Circuit Assembly: triple tuned, 10 kc, 1 kc, 100 cps	HP*	1D-60B	1
Z2	Tuned Circuit Assembly: 10 cycle includes C30, C31, C32, R44, R45, R46	HP*	1D-42A	1
	MISCELLANEOUS			
	Binding Post Assembly: black	HP*	AC-10C	1
	Binding Post Assembly: red	HP*	AC-10D	1
	Binding Post Insulator	HP*	AC-54A	1
	Crystal Oven: aged (less crystal)	HP*	M-69A	1
	Crystal quartz: 100 kc	HP*	M-69A-A2	1
	Holder, fuse:	T*	140-16	2
	Knob: INTENSITY, FOCUS, HORIZ. GAIN, VERT. GAIN	HP*	G-74G	4
	Knob: OUTPUT WAVE, OUTPUT SELECTOR	HP*	G-74N	2
	Relay, plug-in	Phillips Control	49-6	1
	Thermometer: contact, 65C	Precision Thermometer Co.	41-5	1
	Thermometer: 55C to 75C angle	Jensen Inst. Co.	41-6	1
	Terminal strip, Jones type, 8 point	Howard Jones	36-38	1

*** See "List of Manufacturers Code Letters For Replaceable Parts Table".**
 # Total quantity used in the instrument.

LIST OF MANUFACTURERS CODES

CODE LETTER	MANUFACTURER	ADDRESS
A	Aerovox Corp.	New Bedford, Mass.
B	Allen-Bradley Co.	Milwaukee 4, Wis.
C	Amperite Co.	New York, N. Y.
D	Arrow, Hart & Hegeman	Hartford, Conn.
E	Bussman Manufacturing Co.	St. Louis, Mo.
F	Carborundum Co.	Niagara Falls, N. Y.
G	Centralab	Milwaukee 1, Wis.
H	Cinch-Jones Mfg. Co.	Chicago 24, Ill.
HP	Hewlett-Packard Co.	Palo Alto, Calif.
I	Clarostat Mfg. Co.	Dover, N. H.
J	Cornell Dubilier Elec. Co.	South Plainfield, N. J.
K	Hi-Q Division of Aerovox	Olean, N. Y.
L	Erie Resistor Corp.	Erie 6, Pa.
M	Fed. Telephone & Radio Corp.	Clifton, N. J.
N	General Electric Co.	Schenectady 5, N. Y.
O	General Electric Supply Corp.	San Francisco, Calif.
P	Girard-Hopkins	Oakland, Calif.
Q	Industrial Products Co.	Danbury, Conn.
R	International Resistance Co.	Philadelphia 8, Pa.
S	Lectrohm Inc.	Chicago 20, Ill.
T	Littlefuse Inc.	Des Plaines, Ill.
U	Maguire Industries Inc.	Greenwich, Conn.
V	Micamold Radio Corp.	Brooklyn 37, N. Y.
W	Oak Manufacturing Co.	Chicago 10, Ill.
X	P. R. Mallory Co., Inc.	Indianapolis, Ind.
Y	Radio Corp. of America	Harrison, N. J.
Z	Sangamo Electric Co.	Marion, Ill.
AA	Sarkes Tarzian	Bloomington, Ind.
BB	Signal Indicator Co.	Brooklyn 37, N. Y.
CC	Sprague Electric Co.	North Adams, Mass.
DD	Stackpole Carbon Co.	St. Marys, Pa.
EE	Sylvania Electric Products Co.	Warren, Pa.
FF	Western Electric Co.	New York 5, N. Y.
GG	Wilkor Products, Inc.	Cleveland, Ohio
HH	Amphenol	Chicago 50, Ill.
II	Dial Light Co. of America	Brooklyn 37, N. Y.
JJ	Leecraft Manufacturing Co.	New York, N. Y.
KK	Switchcraft, Inc.	Chicago 22, Ill.
LL	Gremar Manufacturing Co.	Wakefield, Mass.
MM	Carad Corp.	Redwood City, Calif.
NN	Electra Manufacturing Co.	Kansas City, Mo.
OO	Acro Manufacturing Co.	Columbus 16, Ohio
PP	Alliance Manufacturing Co.	Alliance, Ohio
QQ	Arco Electronics, Inc.	New York 13, N. Y.
RR	Astron Corp.	East Newark, N. J.
SS	Axel Brothers Inc.	Long Island City, N. Y.
TT	Belden Manufacturing Co.	Chicago 44, Ill.
UU	Bird Electronics Corp.	Cleveland 14, Ohio
VV	Barber Colman Co.	Rockford, Ill.
WW	Bud Radio Inc.	Cleveland 3, Ohio
XX	Allen D. Cardwell Mfg. Co.	Plainville, Conn.
YY	Cinema Engineering Co.	Burbank, Calif.
ZZ	Any brand tube meeting RETMA standards.	
AB	Corning Glass Works	Corning, N. Y.
AC	Dale Products, Inc.	Columbus, Neb.
AD	The Drake Mfg. Co.	Chicago 22, Ill.
AE	Elco Corp.	Philadelphia 24, Pa.
AF	Hugh H. Eby Co.	Philadelphia 44, Pa.
AG	Thomas A. Edison, Inc.	West Orange, N. J.
AH	Fansteel Metallurgical Corp.	North Chicago, Ill.
AI	General Ceramics & Steatite Corp.	Keasbey, N. J.
AJ	The Gudeman Co.	Sunnyvale, Calif.
AK	Hammerlund Mfg. Co., Inc.	New York 1, N. Y.
AL	Industrial Condenser Corp.	Chicago 18, Ill.
AM	Insuline Corp. of America	Manchester, N. H.
AN	Jennings Radio Mfg. Corp.	San Jose, Calif.
AO	E. F. Johnson Co.	Waseca, Minn.
AP	Lenz Electric Mfg. Co.	Chicago 47, Ill.
AQ	Micro-Switch	Freeport, Ill.
AR	Mechanical Industries Prod. Co.	Akron 8, Ohio
AS	Model Eng. & Mfg., Inc.	Huntington, Ind.
AT	The Muter Co.	Chicago 5, Ill.
AU	Ohmite Mfg. Co.	Skokie, Ill.
AV	Resistance Products Co.	Harrisburg, Pa.
AW	Radio Condenser Co.	Camden 3, N. J.
AX	Shallcross Manufacturing Co.	Collingdale, Pa.
AY	Solar Manufacturing Co.	Los Angeles 58, Calif.
AZ	Sealectro Corp.	New Rochelle, N. Y.
BA	Spencer Thermostat	Attleboro, Mass.
BC	Stevens Manufacturing Co.	Mansfield, Ohio
BD	Torrington Manufacturing Co.	Van Nuys, Calif.
BE	Vector Electronic Co.	Los Angeles 65, Calif.
BF	Weston Electrical Inst. Corp.	Newark 5, N. J.
BG	Advance Electric & Relay Co.	Burbank, Calif.
BH	E. I. DuPont	San Francisco, Calif.
BI	Electronics Tube Corp.	Philadelphia 18, Pa.
BJ	Aircraft Radio Corp.	Boonton, N. J.
BK	Allied Control Co., Inc.	New York 21, N. Y.
BL	Augat Brothers, Inc.	Attleboro, Mass.
BM	Carter Radio Division	Chicago, Ill.
BN	CBS Hytron Radio & Electric	Danvers, Mass.
BO	Chicago Telephone Supply	Elkhart, Ind.
BP	Henry L. Crowley Co., Inc.	West Orange, N. J.
BQ	Curtiss-Wright Corp.	Carlstadt, N. J.
BR	Allen B. DuMont Labs	Clifton, N. J.
BS	Excel Transformer Co.	Oakland, Calif.
BT	General Radio Co.	Cambridge 39, Mass.
BU	Hughes Aircraft Co.	Culver City, Calif.
BV	International Rectifier Corp.	El Segundo, Calif.
BW	James Knights Co.	Sandwich, Ill.
BX	Mueller Electric Co.	Cleveland, Ohio
BY	Precision Thermometer & Inst. Co.	Philadelphia 30, Pa.
BZ	Radio Essentials Inc.	Mt. Vernon, N. Y.
CA	Raytheon Manufacturing Co.	Newton, Mass.
CB	Tung-Sol Lamp Works, Inc.	Newark 4, N. J.
CD	Varian Associates	Palo Alto, Calif.
CE	Victory Engineering Corp.	Union, N. J.
CF	Weckesser Co.	Chicago 30, Ill.
CG	Wilco Corporation	Indianapolis, Ind.
CH	Winchester Electronics, Inc.	Santa Monica, Calif.
CI	Malco Tool & Die	Los Angeles 42, Calif.
CJ	Oxford Electric Corp.	Chicago 15, Ill.
CK	Camloc-Fastener Corp.	Paramus, N. J.
CL	George K. Garrett	Philadelphia 34, Pa.
CM	Union Switch & Signal	Swissvale, Pa.
CN	Radio Receptor	New York 11, N. Y.
CO	Automatic & Precision Mfg. Co.	Yonkers, N. Y.
CP	Bassick Co.	Bridgeport 2, Conn.
CQ	Birnbach Radio Co.	New York 13, N. Y.
CR	Fischer Specialties	Cincinnati 6, Ohio
CS	Telefunken (c/o MVM, Inc.)	New York, N. Y.
CT	Potter-Brumfield Co.	Princeton, Ind.
CU	Cannon Electric Co.	Los Angeles, Calif.
CV	Dynac, Inc.	Palo Alto, Calif.
CW	Good-All Electric Mfg. Co.	Ogallala, Nebr.

WARRANTY

All our products are warranted against defects in materials and workmanship for one year from the date of shipment. Our obligation is limited to repairing or replacing products (except tubes) which prove to be defective during the warranty period. We are not liable for consequential damages.

For assistance of any kind, including help with instruments under warranty, contact your authorized hp Sales Representative for instructions. Give full details of the difficulty and include the instrument model and serial numbers. Service data or shipping instructions will be promptly sent to you. There will be no charge for repair of instruments under warranty, *except transportation charges.* Estimates of charges for non-warranty or other service work will always be supplied, if requested, before work begins.

CLAIM FOR DAMAGE IN SHIPMENT

Your instrument should be inspected and tested as soon as it is received. The instrument is insured for safe delivery. If the instrument is damaged in any way or fails to operate properly, file a claim with the carrier or, if insured separately, with the insurance company.

SHIPPING

On receipt of shipping instructions, forward the instrument prepaid to the destination indicated. You may use the original shipping carton or any strong container. Wrap the instrument in heavy paper or a plastic bag and surround it with three or four inches of shock-absorbing material to cushion it firmly and prevent movement inside the container.

GENERAL

Your authorized hp Sales Representative is ready to assist you in any situation, and you are always welcome to get directly in touch with Hewlett-Packard service departments:

CUSTOMER SERVICE

Hewlett-Packard Company
395 Page Mill Road
Palo Alto, California, U.S.A.
Telephone: DAvenport 6-1755
Direct Dial Area Code 415
TWX No. PAL AL 117-U
Cable: "HEWPACK"

OR (In Western Europe)

Hewlett-Packard S.A.
Rue du Vieux Billard No. 1
Geneva, Switzerland
Telephone: (022) 26. 43. 36
Cable: "HEWPACKSA"

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